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(54) **Vehicle Load Monitor**

(57) A load monitor for use in a road vehicle provides a display for the driver of the vehicle of one or more vehicle weights or loads so that a check can be made by the driver to ensure that maximum legal or safe loading is not exceeded. The load monitor comprises sensors 21—24 mounted on the vehicle chassis and responsive to loading of the chassis to produce an output which varies with the applied load, computing apparatus 25 programmed to produce in response to the sensor output and vehicle parameters a computer output representative of the load, and a display unit 26 in the cab of the vehicle for producing a visual indication of the computer output.

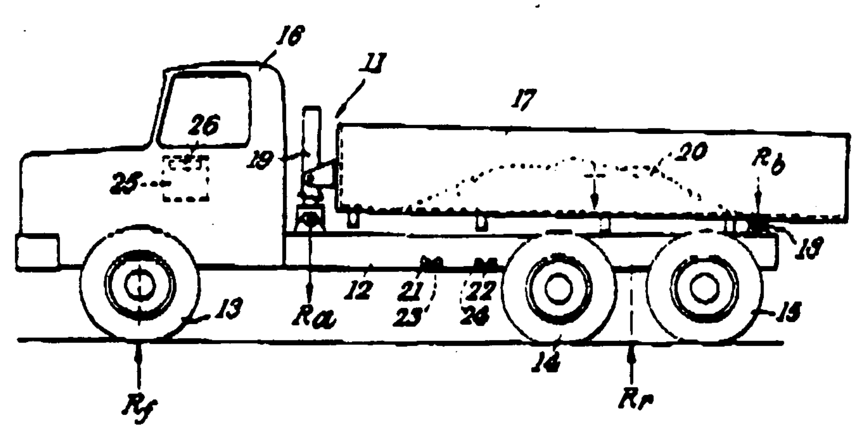

Fig.1.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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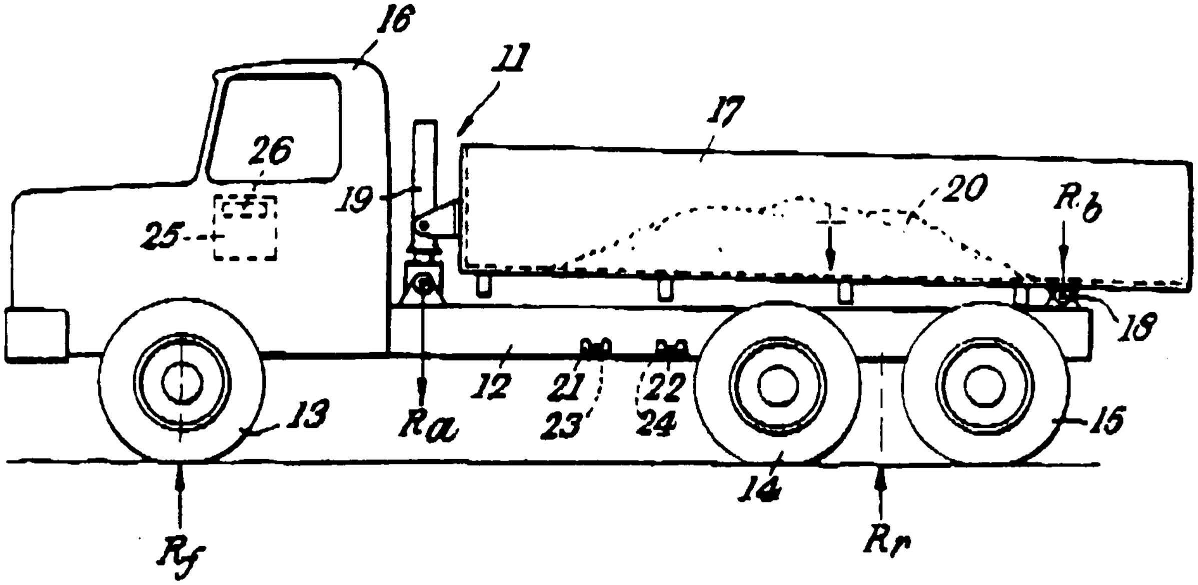

Fig. 1.

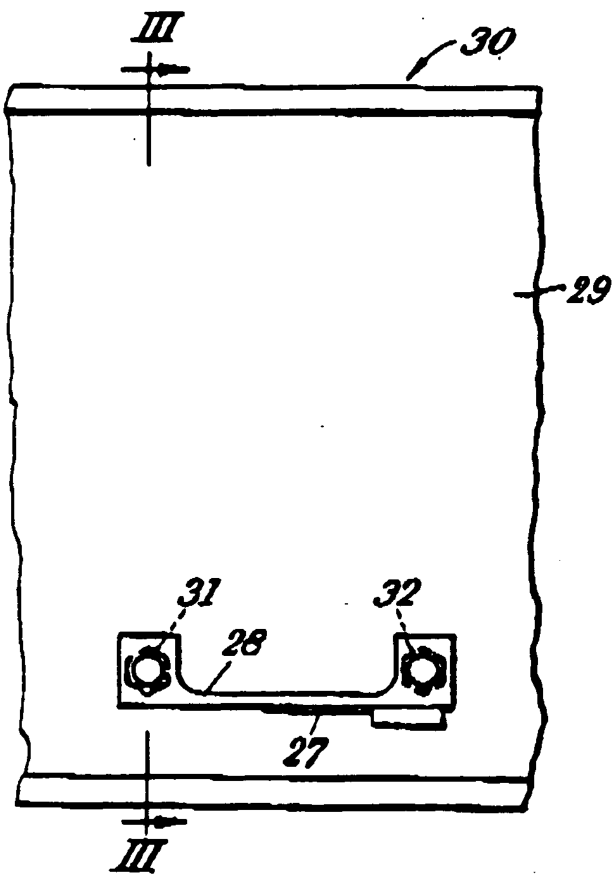

Fig. 2.

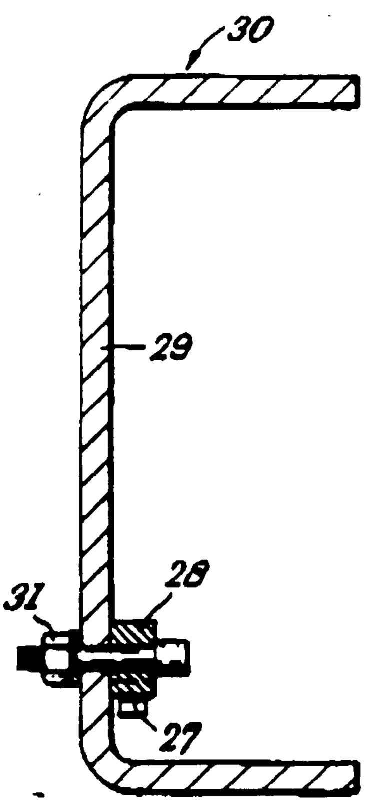

Fig. 3.

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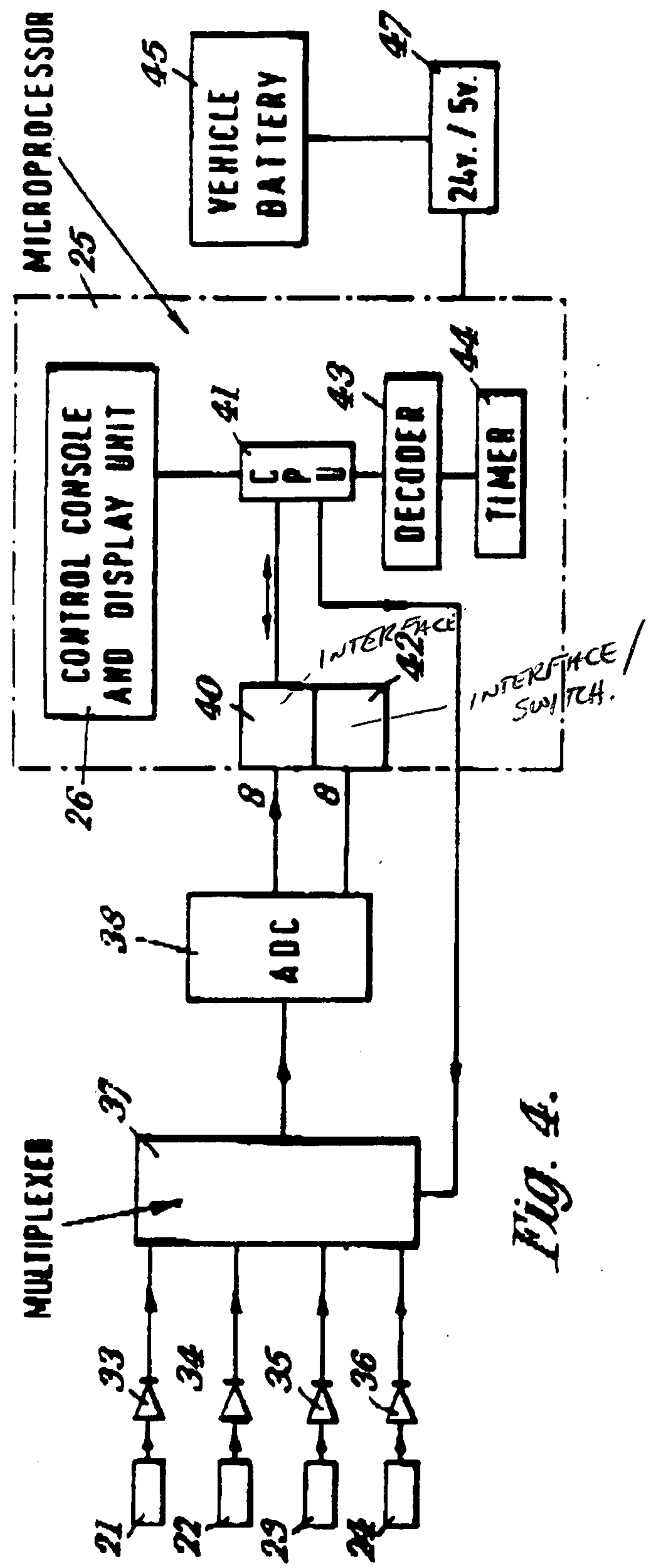

Fig. 4.

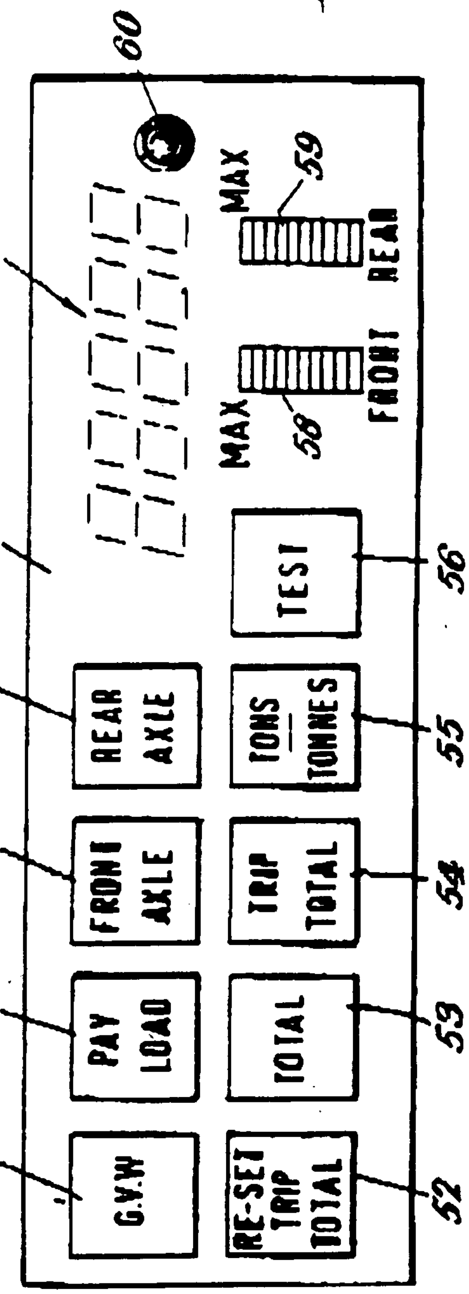

Fig. 5.

SPECIFICATION

Vehicle Load Monitor

The present invention relates to a load monitoring system for a vehicle and is particularly although not exclusively concerned with a load monitoring system for a road vehicle of the kind having a chassis supported by front and rear road wheels and a load carrying body mounted on the chassis.

Vehicles of the above kind are subject to vehicle safety legislation limiting gross vehicle weight and axle loads. It is therefore not uncommon for such vehicles to be loaded with payloads below the maximum permitted for the vehicle to ensure that the gross vehicle weight and axle loads are not exceeded.

It is an object of the present invention to provide a load monitoring system for a vehicle of the above kind, which provided on the vehicle a display of one or more vehicle weights or loads, so that a check can readily be made to ensure that the maximum legal or safe loading is not exceeded.

According to a first aspect of the present invention, there is provided a load monitoring system for a vehicle comprising sensor means for mounting on load support means of the vehicle and responsive to a variable of the load support means which varies with the load applied thereto to produce a sensor output, computing apparatus programmable to produce in response to the sensor output and vehicle parameters a computer output representative of the applied load and display means for producing a visual indication of the computer output.

Preferably, the sensor means is provided for mounting at a predetermined position or positions on the load support means and the computing apparatus is programmed with predetermined vehicle parameters to produce one or more of a plurality of computer outputs representing the load or loads applied to the load support means at one or more of a plurality of positions thereon remote from the predetermined position of the sensor means.

In a preferred embodiment of the invention, the sensor means comprises a first sensor for mounting on the load support means at a first position thereof and responsive to a variable of the load support means which varies with the load applied thereto at the first position to produce a first sensor output signal and a second sensor for mounting on the load support means at a second position thereof spaced from the first position and responsive to a variable of the load support means which varies with the load applied thereto at the second position to produce a second sensor output signal and the computing apparatus is programmed to produce the computer output or outputs from the first and second sensor signals and predetermined vehicle parameters.

According to a second aspect of the present invention, there is provided a vehicle including a load monitoring system according to the first aspect of the invention, the load support means comprising a chassis, front and rear wheeled supports supporting the chassis which extends therebetween and a load supporting body mounted on the chassis. The load supporting body may in a load measuring disposition thereof be supported totally by front body support means at the front of the body and by rear body support means at the rear of the body. With this arrangement, the vehicle parameters are then preferably obtained from measurements with the load supporting body in the load measuring disposition and the computing apparatus arranged to generate computer output when the load supporting body is in the load measuring disposition.

The rear body support means may be such as to allow for the raising of the front of the body and the front body support means may comprise hydraulic ram means for raising the front end of the body, whereby the body can be raised to the load measuring disposition in which it is totally supported by the rear support means and the hydraulic ram means.

In one of the embodiments of the invention hereinafter to be described one of the sensors is made responsive to a variable of the hydraulic ram means which varies with the load applied to it and the other of the sensors is made responsive to a variable of the rear body support means which varies with the load applied to it.

In an alternative embodiment of the invention hereinafter to be described, the two sensors are mounted on the chassis at longitudinally spaced positions thereon and are responsive to strains produced in the chassis at those positions from the loads applied thereto. In the preferred arrangement the two sensors are mounted at longitudinally spaced positions on one side of the chassis and the sensor means comprises two further sensors mounted on the other side of the chassis at longitudinally spaced positions thereon and responsive to strains produced at those positions from the loads applied thereto to produce two further sensor output signals. The computing apparatus is then programmed to produce in response to the four sensor output signals a computer output representing the sum of the loads applied to the two sides of the chassis. The computing apparatus may, if desired, also be programmed to produce a computer output representing a difference in the loads applied to the two sides of the chassis to provide an indication of a lateral imbalance of the loads.

The front and rear wheeled supports of the vehicle may comprise front and rear wheel axle arrangements supporting front and rear road wheels, the vehicle parameters may include unladen vehicle front axle and rear axle loads, predetermined maximum laden vehicle front axle and rear axle loads and constants associated with vehicle geometry and the computing apparatus may be

programmed to produce from the sensor output signals computer outputs representing the front and rear axle loads.

The computing apparatus may furthermore be programmed to produce a computer output representing the payload carried by the load carrying body from the front and rear axle loads and the unladen vehicle axle loads. In addition, the computing apparatus may be programmed to produce from the front and rear axle loads a computer output representing the gross vehicle weight.

The computing apparatus may comprise a control console mounted in the cab of the vehicle and including instruction keying devices for instructing the computing apparatus to produce any selected one or ones of a plurality of computer outputs and the display means may provide a digital display of the selected computer output or outputs. In addition, the display means may include front axle and rear axle display units each composed of light emitting diode bars arranged in a stack and the computer outputs representing the front axle and rear axle loads may produce a cumulative illumination of successive bars with increasing axle load up to illumination of all the bars, which indicates a maximum permitted axle load.

Two embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:—

Fig. 1 is a schematic side elevation of a motor vehicle embodying a load monitoring system according to the invention,

Fig. 2 is a scrap elevational view of part of the chassis of the vehicle shown in Fig. 1, fitted with a sensor of the monitoring system,

Fig. 3 is a cross-section of the part of the chassis shown in Fig. 2, taken on the line III—III in Fig. 2.

Fig. 4 is a block schematic diagram of the load monitoring system provided on the vehicle shown in Fig 1, and

Fig. 5 is a schematic front elevation of a control console and display unit of the monitoring system shown in Fig. 4 and mounted in the cab of the vehicle shown in Fig. 1.

Referring first to Fig. 1, a motor vehicle 11 comprises a chassis 12 supported by a pair of front wheels 13 and two pairs of rear wheels 14 and 15, a driver's cab 16 and a load carrying body 17 which is mounted on the chassis 12 by a transverse hinge 18 at the rear end of the chassis and a hydraulic ram 19 at the front end of the body, which can be raised by the actuation of the ram 19 to turn the body 17 about the transverse hinge 18 into a sharply inclined position for disposing of a load 20 contained in the body 17. In the position shown in Fig. 1, the load carrying body 17 is supported by the ram 19 in a slightly raised position in which it is totally supported by the ram 19 and the hinge 18. In a fully lowered position of the ram 19, the base of the body 17 rests on the chassis between the ram 19 and the hinge 18, thereby relieving the ram 19 from supporting the front of the body 17 during transportation of the load 20.

A pair of transducers 21 and 22 are mounted on the nearside of the chassis 12 in positions longitudinally spaced from each other and a further pair of transducers 23 and 24 are mounted on the offside of the chassis 12 in the same positions as those of the transducers 21 and 22. The transducers 21 to 24 are coupled to a microprocessor 25 housed in the cab 16 and including an operator's control console and display unit 26 located in a position in the cab for easy operation and viewing by the driver of the vehicle.

Referring now to Figs. 2 and 3, each of the transducers 21 to 24 comprises a strain gauge 27 mounted on a strain link 28 secured to a web 29 of a longitudinal channel member 30 of the chassis 12 by bolts 31 and 32. The strain gauge 27 is connected in to one arm of a conventional temperature compensating bridge network and a compensating element, mounted in the same location as the gauge 27, is connected in an adjacent arm of the bridge network. A voltage is applied to the appropriate diagonal of the bridge and an output obtained from the other diagonal to produce a signal representative of the bending of the chassis member at the location of the strain gauge 27.

Referring now to Fig. 4, the output signals from the transducers 21 to 24 are amplified in amplifiers 33 to 36 and applied to separate input terminals of a multiplexer 37. The signals are in analogue form and the multiplexer provides for the serial transmission of them in separate time division channels through an analogue-to-digital converter 38. The analogue signals applied to the converter 38 are converted thereby to digital signals in an eight-bit code in parallel bit form suitable for feeding to the microprocessor 25. The digital signals are fed via a conventional peripheral interface adaptor unit 40 to the central processing unit 41 of the microprocessor, the interface adaptor unit 40 providing for modification of the digital signals into a form acceptable for use in the central processing unit 41. A further interface adaptor 42 under the control of the central processing unit 41 provides for switching of the converter 38. The microprocessor 25 includes a decoder 43, timer 44 and the control console and display unit 26. The decoder 43 preprocesses commands from the control console and display unit 26 and the timer 44 provides the necessary timing signals for multiplexer channel selection controlled by the central processing unit 41. The microprocessor 25 is arranged to be supplied with power from a vehicle battery 45 via a voltage converter 47 to provide 24 volt and 5 volt supplies.

Referring now to Fig. 5, the control console and display unit 26 is provided with a plurality of control push buttons for use by the driver of the vehicle in transmitting instructions to the

microprocessor, a digital display 57, two further display devices 58 and 59 and a warning lamp 60, the functions of which will hereinafter be described.

The microprocessor 26 is programmed to produce computer outputs representing in digital form on the digital display 57 the front axle and rear axle loads upon depression of the push button 50 or 51, the gross vehicle weight upon depression of the push button 48, the payload carried by the vehicle body 17 upon depression of the push button 49, the total of the payloads during the life of the vehicle upon depression of the button 53, the trip total of payloads carried throughout a period commenced by depression of the reset trip total push button 52, the load displayed on the digital display 57 being in British or metric tons by appropriate depression of the push button 55. In addition, the computer outputs representing the front axle and rear axle loads are also displayed on display devices 58 and 59, each of which comprises a plurality of light emitting diode bars arranged in a stack and illuminated successively and cumulatively in response to increasing axle load and so calibrated as to show complete illumination of the stack when the computer output represents the maximum permitted axle load. The warning lamp 60 is arranged to be energised when the load displayed on the digital display 57 exceeds the maximum permitted or safe load.

To produce the above-mentioned computer outputs, the microprocessor needs to be programmed for calculating from the outputs of the four transducers 21 to 24 the front axle and rear axle loads. From the values of the front axle and rear axle loads the other computer outputs can readily be obtained by the microprocessor. In particular, the unladen weight of the vehicle is entered in to the microprocessor and the two axle loads added together and subtracted from the unladen weight to produce the payload carried by the vehicle. The front and rear axle loads may also be added together to produce the gross vehicle weight. The total of the payloads throughout the life of the vehicle may be obtained by a simple arithmetic operation and a read-out in British or metric tons can be obtained by applying a simple multiplication factor.

It is proposed in the present embodiment of the invention to programme the computing apparatus for calculation of the front axle and rear axle loads from transducer output signals obtained when the load carrying body 17 is in the slightly raised position as shown in Fig. 1 so that the body 17 and the payload are totally supported by the ram 19 and the hinge 18 and can be represented by point loads R_a and R_b. If the front axle reaction is taken to be R_f and the total rear axle reaction to be R_r then it can be shown that following calibration for the particular vehicle the front and rear axle loads can be calculated knowing only the values of the transducer output signals.

For calibration of the transducers 21 to 24 the vehicle is taken to a weighbridge. At the weighbridge, the vehicle 11 with the body 17 empty and in the slightly raised position is moved to a position in which the front wheels 13 rest on the weighbridge. The output signals from the transducers 21 to 24 are recorded as well as the unladen front axle load. The vehicle 11 is then moved to a position in which the rear wheels only are on the weighbridge and the unladen rear axle load measured and recorded. The vehicle with the body 17 still in the slightly raised position is then loaded with a payload providing maximum permitted front and rear axle loads, which are measured and recorded, together with the measurement and recording of the transducer output signals under this maximum loading.

The data obtained at the weighbridge is then used to calculate the constants in the equations for evaluating the front and rear axle loads from the transducer output signals and the constants programmed into the computing apparatus.

Equations for calculating the front and rear axle loads from the transducer output signals may be obtained as follows:—

Let R_a=Ram cradle bracket point load
R_b=Hinge bracket point load
R_f=Front axle reaction
R_r=Total rear axle reaction
e_1=Output signal of one of the front transducers 21 and 23
e_2=Output signal of one of the rear transducers 22 and 24
$k, k_1, k_2, \ldots k_{32}$=Constants.

Taking moments about R_b

$$R_a k = R_r k_1 + R_f k_2$$
$$R_a = R_r k_3 + R_f k_4 \qquad (1)$$

taking bending moments:—

$$e_1 = R_f k_5 - R_a k_6$$

Substituting equation (1) for R_a in above equation:—

$$\begin{aligned} e_1 &= R_f k_5 - k_6(R_r k_3 + R_f k_4) \\ &= R_f k_5 - R_r k_7 - R_f k_8 \qquad (2) \\ \therefore\ e_1 &= R_f k_9 - R_r k_7 \end{aligned}$$

Taking bending moments:—

$$e_2 = R_f k_{10} - R_r k_{11}$$

Substituting equation (1) in above equation

$$\begin{aligned} e_2 &= R_f k_{10} - k_{11}(R_f k_3 + R_r k_4) \\ &= R_f k_{10} - R_f k_{12} - R_r k_{13} \\ e_2 &= R_f k_{14} - R_r k_{12} \end{aligned} \qquad (3)$$

Add equations (2) and (3)

$$e_1 + e_2 = R_f k_{15} - R_r k_{16} \qquad (4)$$

Now from equation (2)

$$R_f = \frac{e_1 + R_r k_7}{k_6}$$

$$\therefore\ R_f = e_1 k_{17} + R_r k_{18}$$

Substituting above equation for R_f in equation (4)

$$\begin{aligned} &\therefore\ (e_1 + e_2) = k_{15}(e_1 k_{17} + R_r k_{18}) - R_r k_{16} \\ &(e_1 + e_2) = k_{19} e_1 + k_{20} R_r - R_r k_{16} \\ &(e_1 + e_2) = e_1 k_{19} + R_r k_{21} \\ &(e_1 + e_2) = e_1 k_{19} = R_r k_{21} \\ &k_{22} e_1 + k_{22} e_2 - k_{23} e_1 = R \end{aligned} \qquad (5)$$

Expanding equation (5) we have:

$$\begin{aligned} &k_{22} e_1 + k_{22} e_2 - k_{23} e_1 = r_r \\ &\therefore\ e_1 k_{24} + e_2 k_{22} = R_r \end{aligned} \qquad (5A)$$

The constants k_{24} and k_{22} can be found using simultaneous equations from data obtained at the calibration stage. Also from equation (2)

$$R_r = \frac{R_f k_6 - e_1}{k_7}$$

$$R_r = R_f k_{25} - e_1 k_{26}$$

Substituting above equation for R_r in equation (4)

$$\begin{aligned} &(e_1 + e_2) = R_f k_{15} - k_{16}(R_f k_{25} - k_{26} e^1) \\ &= R_f k_{15} - R_f k_{27} + e_1 k_{28} \end{aligned} \qquad (6)$$

$$\begin{aligned} &(e_1 + e_2) - e_1 k_{28} = R_f k_{29} \\ &k_{30}(e_1 + e_2) - e_1 k_{31} = R_f \end{aligned}$$

Expanding equation (6) we have:

$$\begin{aligned} &k_{30} e_1 + k_{30} e_2 - k_{31} e_1 = R_f \\ &k_{32} e_1 + k_{30} e_2 = R_f \end{aligned} \qquad (6A)$$

The constants k_{32} and k_{30} can be found using simultaneous equations from data obtained at the calibration stage.

The transducers 21 to 24 may if desired be located at positions on the chassis 12 different from those provided in the embodiment of the invention hereinbefore described and the choice of position will be limited to some extent by the configuration of the vehicle to which the monitoring system is applied. Furthermore, for some vehicle configurations it may be necessary or desirable to employ three transducer pairs arranged in longitudinally spaced relation on the chassis. Where three such pairs of transducers are employed the constants which appear in the equations relating transducer outputs e_1, e_2 and e_3 to front and rear axle reactions R_f and R_r and which are dependent upon vehicle geometry may be calculated from calibration measurements of the transducer output signals for three different front axle and rear axle loads.

In an alternative embodiment of the invention now to be described, the front transducers 21 and

23 are replaced by a transducer pair mounted on the cradle bracket of the ram 19 for producing a transducer output signal e_1 representative of the ram load R_a. The rear transducers 22 and 24 are likewise replaced by a transducer pair mounted on the brackets of the hinge 18 for producing a transducer output signal e_2 representative of the load R_b acting on the hinge. Equations may readily be derived for the front and rear axle reactions R_f and R_r as functions of e_1 and e_2. The equations are linear and of the form:—

$$R_f = e_1k_1 - e_2k_2$$
$$R_r = e_1k_3 - e_2k_4$$

where k_1 to k_4 are constants dependent on vehicle geometry.

The constants for the above equations can be found from two sets of values for R_f, R_r, e_1, and e_2 obtained at the calibration stage. The constants thus obtained are then programmed into the computer for the calculation of computer outputs representing the front axle and rear axle loads.

During calibration and for the purpose of obtaining computer outputs the load carrying body 17 is moved to the slightly raised position as shown in Fig. 1 so that the load of the body 17 including the payload is applied at the ram 19 and the hinge 18 as point loads.

The microprocessor 25 is furthermore programmed with maximum permissible axle loads and gross vehicle weight to produce illumination of the warning lamp 60 when the value of the digital display 57 exceeds the permitted value.

Other computer outputs may, if desired, be provided. For example, a charge per unit payload may be entered into the microprocessor 25 and a monetary charged related to the payload displayed at the control console and display unit 26. A display of the total number of tipping operations may also, if desired, be provided. A display may also be produced showing any imbalance of the load across the width of the chassis 12, making the driver aware of dangerously out-of-balance loads.

While the embodiments of the invention hereinbefore described have included a vehicle with a tipping body, the load monitoring system may if desired be used with a non-tipping vehicle. In this case, different equations would need to be solved by the microprocessor 25 and additional transducers may be needed to enable the constants of the equations to be determined.

The monitoring system may also be used on articulated vehicles with, for example, one of the transducers mounted in a king pin support for the vehicle. While the vehicle described with reference to Fig. 1 includes a single front axle and a rear axle arrangement employing two rear axles the invention is equally applicable to vehicles with other axle configurations.

Claims

1. A load monitoring system for a vehicle comprising sensor means for mounting on load support means of the vehicle and responsive to a variable of the load support means which varies with the load applied thereto to produce a sensor output, computing apparatus programmable to produce in response to the sensor output and vehicle parameters a computer output representative of the applied load and display means for producing a visual indication of the computer output.

2. A system according to Claim 1 wherein the sensor means is provided for mounting at a predetermined position or positions on the load support means and wherein the computing apparatus is programmed with predetermined vehicle parameters to produce one or more of a plurality of computer outputs representing the load or loads applied to the load support means at one or more of a plurality of positions thereon remote from the predetermined position or positions of the sensor means.

3. A system according to Claim 2, wherein the sensor means comprises a first sensor for mounting on the load support means at a first position thereof and responsive to a variable of the load support means which varies with the load applied at the first position to produce a first sensor output signal and a second sensor for mounting on the load support means at a second position thereof spaced from the first position and responsive to a variable of the load support means which varies with the load applied at the second position to produce a second sensor output signal, and wherein the computing apparatus is programmed to produce the computer output or outputs from the first and second sensor output signals and predetermined vehicle parameters.

4. A vehicle including a load monitoring system according to Claim 3, wherein the load support means comprises a chassis, front and rear wheeled supports supporting the chassis extending therebetween, and a load supporting body mounted on the chassis.

5. A vehicle according to Claim 4, wherein the load supporting body in a load measuring disposition thereof is supported totally by front body support means at the front of the body and rear body support means at the rear of the body, wherein the vehicle parameters are obtained from measurements with the load supporting body in the load measuring disposition and wherein the computing apparatus is arranged to produce computer output when the load supporting body is in the load measuring disposition.

6. A vehicle according to Claim 5, wherein the rear body support means is such as to allow for the raising of the front of the body and wherein the front body support means comprises hydraulic ram

means for raising the front end of the body to bring the body to the load measuring disposition in which it is totally supported by the rear body support means and the hydraulic ram means.

7. A vehicle according to Claim 6, wherein one of the sensors is responsive to a variable of the hydraulic ram means which varies with the load applied thereto and the other of the sensors is responsive to a variable of the rear body support means which varies with the load applied thereto.

8. A vehicle according to Claim 4, 5 or 6 wherein the two sensors are mounted on the chassis at longitudinally spaced positions thereon and are responsive to strains produced in the chassis at those positions from the load applied thereto.

9. A vehicle according to Claim 8, wherein the two sensors are mounted at longitudinally spaced positions on one side of the chassis, wherein the sensor means comprises two further sensors mounted on the other side of the chassis at longitudinally spaced positions thereon and responsive to strains produced at those positions from the load applied thereto to produce two further sensor output signals, and wherein the computing apparatus is programmed to produce in response to the first and second sensor output signals and the further sensor output signals computer outputs representative of the sum of the loads applied to the two sides of the chassis.

10. A vehicle according to Claim 9, wherein the computing apparatus is programmed to produce a computer output representing a difference in the loads applied to the two sides of the chassis to provide an indication of a lateral imbalance of the loads.

11. A vehicle according to any of Claims 4 to 10, wherein the front wheeled support comprises a front axle arrangement supporting front road wheels and wherein the rear wheeled support comprises a rear axle arrangement supporting rear road wheels, wherein the vehicle parameters include unladen front axle and rear axle loads predetermined maximum laden front and rear axle loads and constants associated with vehicle geometry and wherein the computing apparatus is programmed to produce from the sensor output signals computer outputs representing the front axle and rear axle loads.

12. A vehicle according to Claim 11, wherein the computing apparatus is programmed to produce a computer output representing the payload carried by the load carrying body from the front and rear axle loads and the unladen vehicle axle loads.

13. A vehicle according to any of the preceding claims, wherein the computing apparatus comprises a control console mounted in the cab of the vehicle and including instruction keying devices for instructing the computing apparatus to produce any selected one or ones of a plurality of computer outputs, and wherein the display means provides a digital display of the selected computer output or outputs.

14. A vehicle according to Claim 13 wherein the display means includes a front axle display unit and a rear axle display unit, each of which is composed of light emitting diode bars arranged in a stack and wherein computer outputs representing the front axle and rear axle loads produce a cumulative illumination of successive bars with increasing load up to illumination of all the bars, which indicates a maximum permitted axle load.

15. A vehicle according to any of Claims 11 to 14 wherein the computing apparatus is programmed to produce from the front and rear axle loads a computer output representing the gross vehicle weight.

16. A load monitoring system for a vehicle, substantially as hereinbefore described with reference to the accompanying drawings.

17. A vehicle substantially as hereinbefore described with reference to the accompanying drawings.

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